I J C T A, 9(37) 2016, pp. 529-536

Real Time Control for Charging Optimization in Hybrid Electric Vehicles

Vijayalakshmi. G* and Ramesh. K**

Abstract: A huge inrush of Hybrid Electric Vehicles (HEVs) is envisioned in the future. As a new generation of transport, electric vehicles have several advantages compared with traditional vehicle in the aspects of energy conservation and emissions reduction and reducing human dependence on traditional fossil fuel. As increase in Electric Vehicle (EV) around the world, making EVs user friendly becomes more important. The main challenge in usage of HEV is the charging time required for the batteries used in HEV, lack of charging stations and therefore charging within existing distribution system infrastructure. To provide a reliable journey for vehicles this system is proposed. This is a mobile information system for EV and it is aimed at giving the relevant information about the electric vehicle. With the Android application, the users will be able to save time and plan their ways accordingly.

Index Terms: Hybrid Electric Vehicle (HEV), State of Charge (SOC), Charging Stations (CS), Charging Station Selection Server (CSS)

1. INTRODUCTION

Electric vehicles (EVs) have received considerable attention in recent times as an eco-friendly and cost effective alternative over conventional vehicles driven by internal combustion engines (ICEs). [1] They have lower operating costs with respect to ICE vehicles and can be also charged with locally produced renewable energy sources (RESs). [2]. Connection to the electric power grid allows opportunities such as ancillary services, reactive power support, tracking the output of renewable energy sources, and load balance. The important issue about EV charging is to deploy an efficient smart grid network that can effectively and conveniently charge the EVs. The secondary batteries are the main sources of electric vehicles. Thus, the energy management and the battery capacity plays a vital role in the development of hybrid electric vehicles (HEV). [3] The main challenge in the HEV is the charging time required for the batteries and insufficiency of charging stations (CS). [4] The second challenge for the EV's is their battery capacity which ranges from 8.6 KWh to 15.2 KWh. The consequent disadvantage is that the charging time for above mentioned size, in a level 1 household charger (120 V, 50 Hz, 15-20 A) is more than 15 hours. [5] In future, the number of electric vehicles will be increasing to a greater extent, these electric vehicles have to re-charge their battery in a place (i.e.) charging station, so there will be a growing need of public accessing charging stations. [6] This will have a significant impact on the power systems like transformers, protection devices etc. With respect to the varying load, it will have an impact on the consumers and vendors due to the traffic at these station, waiting time for charging the vehicles will increase etc. So to improve all these factors there should be a proper monitoring systems to manage them, like the smart grid technologies monitoring the load on the power grids [7-9]. Therefore both the consumer and vendor will get assistance from a communication system which shares useful data regarding the charging station, whether the charging slots are free, rate at which charging is done and the cost per unit. This is basically what is known as vehicle to grid communication (V2G). [10] The objective is to develop an application it connects the user and vendor. The added feature in the developed application is the vendor can sell their entity through the means of bidding process. It can be done by adding the charging station through online GPS map, so that the viewer can choose the closest station based on the cost per unit. Figure 1 explains the load forecasting. Load forecasting helps to

* Electronics and Communication Engineering, SRM University, Chennai, India. *Email: madhugananathan@gmail.com*
** Electronics and Communication Engineering, SRM University, Chennai, India. *Email: ramesh.kr@ktr.srmuniv.ac.in*

predict the peak loads, according to the peak load the number of cars that can be charged is estimated. The information is stored in the charging station server.

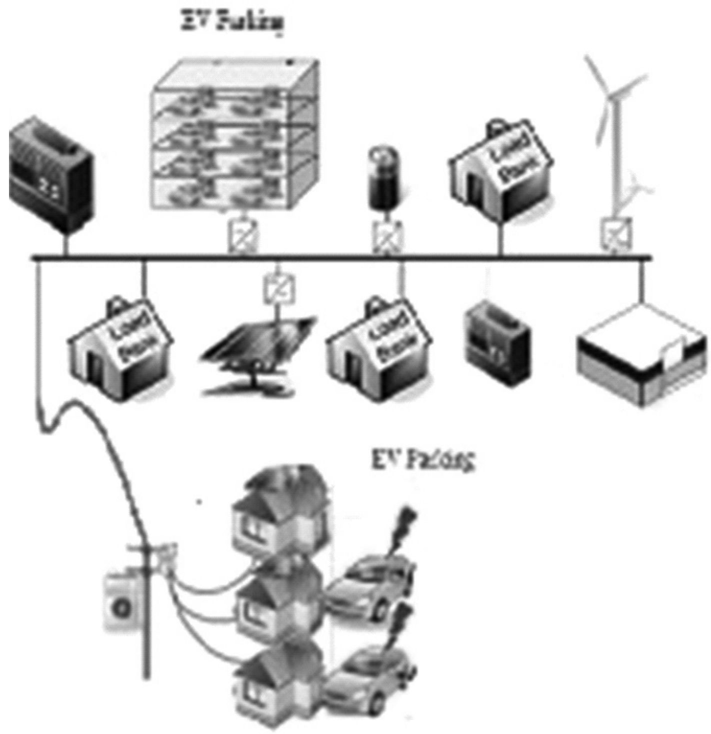

Figure 1: Load Forecasting

As we known, the most distinct characteristic of batteries is longer recharging times and short battery cycle life, which badly restrict the development of EV. [11] As for the EV charging station, its main objectives include certainly short recharge times, high charge efficiencies and improved battery life. Charge times and cycle life of battery are closely linked with charging pattern. Choosing the right charging pattern base on the actual condition ensures high charge efficiencies and improved cycle life. In the proposed idea the mobile application is used to show the details of the electric vehicle and it is communicated to the charging station server. The charging station server indicates the availability of the parking slots to the users so that they can prefer the charging stations. This helps the EV users to save their time.

2. HARDWARE ARCHITECTURE

The hardware architecture is mainly developed for the convenience of the electric vehicle users. The main modules and functionalities are illustrated in Figure 2 and are described below

A. EV Charging module

1. ***House-hold Charging point:*** Level 1 charging equipment is standard on vehicles and therefore is portable and does not require the installation of charging equipment. On one end of the provided cord is a standard three prong household plug. On the other end is a connector, which plugs into the vehicle. Depending on the battery technology used in the vehicle, Level 1 charging generally takes 8 to 12 hours to completely charge a fully depleted battery. [19].

2. ***Public Charging Stations:*** The public charging equipment offers charging through a 240 V, AC plug and requires installation of home charging or public charging equipment. These units require a dedicated 40 amp circuit. Public charging equipment is compatible with all electric vehicles and plugin electric hybrid vehicles. Public chargers have a cord that plugs directly into the vehicle in the same connector

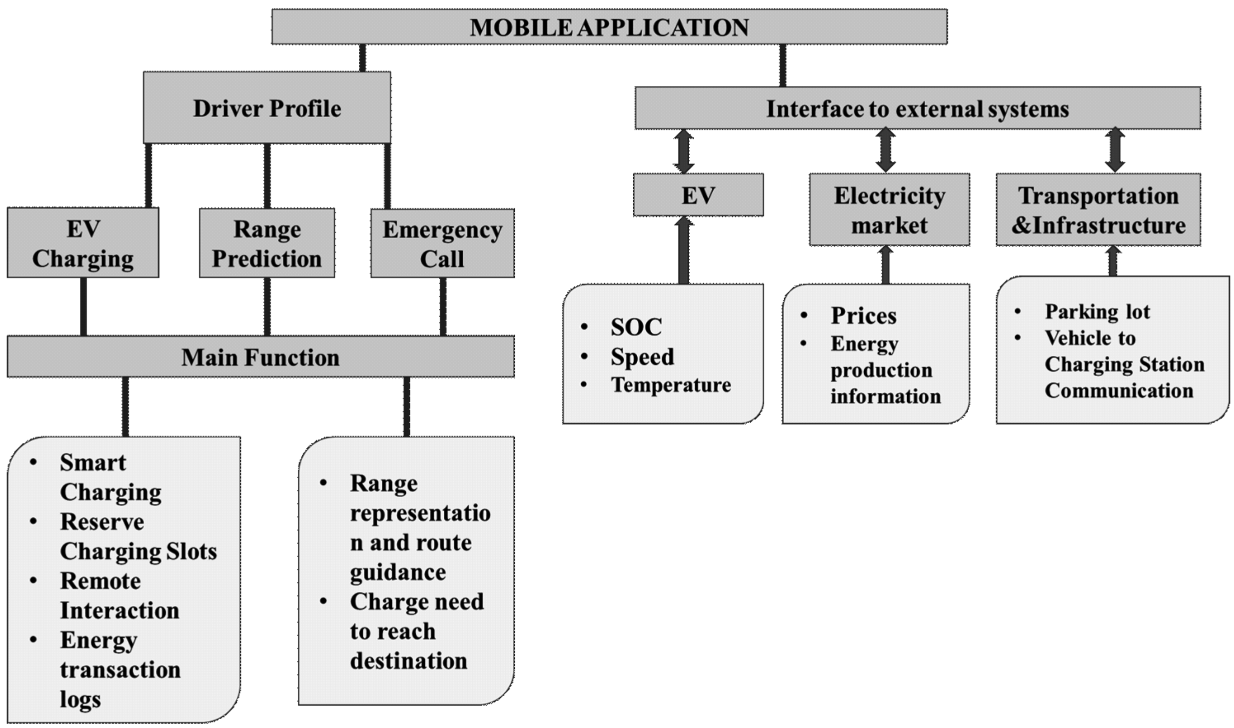

Figure 2: Android application main modules and functionalities

location used for Level 1 equipment. Depending on the battery technology used in the vehicle, public charging generally takes 4 to 6 hours to completely charge a fully depleted battery. Charging time can increase in cold temperature. Lithium ion batteries supports the charging temperature of 0°C to 45°C (32°F to 113°F) and discharging temperature of –20°C to 60°C (–4°F to 140°F). No charging is permitted below freezing point. There will be good charging and discharging performance at higher temperatures but the life of the battery will be affected. Public chargers are commonly found in residential settings, public parking areas, places of employment and commercial settings [20].

B. Range Prediction

It provides guidance to the CS with the possibility of reserving a charging slot using the range charging assistant function. Based on the battery state-of-charge (SOC) [21], and remaining distance, the system can calculate the minimum energy required in the batteries and it indicates the driver whether the destination can be reached or not with the present SOC. So that the users can make it possible to reach the desired destination or they can plan to reach the nearest CS. The range prediction can be estimated using the formula given in Distance estimation in Chapter III.

C. Emergency Call

The Emergency call system paves the way to access the mobile charging station. It is accessed when the nearest charging station cannot be reached. When the EV's battery SOC is very low, the EV's location will be sent to the mobile charging stations. The SOC describes the Battery's remaining power. The SOC and DOD is defined by the following equations (1) and (2)

$$SOC = \left(Q_{total} - \frac{Q_{out}}{Q_{total}} \right) \times 100 \tag{1}$$

$$DOD = 1 - SOC \tag{2}$$

Where Q_{total} is the charge available before discharging of the battery

Q_{out} is the charge during discharging of the battery.

DOD is the Depth of Discharge

D. External Interface System

The Battery SOC, speed and the temperature must be communicated to the android application via Bluetooth. Bluetooth is preferred because it can communicate up to the distance of 100 meters. So that we can achieve the prediction of reaching the destination.

E. Points of Interest

Information related to points of interest (POI) is preloaded on the system, such that the driver can perform a quick search for any desired POI near the present location. This information is also used for guidance to FEV battery charging points that remain at a predefined distance [22].

F. Parking Places

Information associated with available parking places and remote reservation of EVs battery charging slots [22-23]. And the nearest parks and motels are also indicated.

3. RESULTS AND DISCUSSIONS

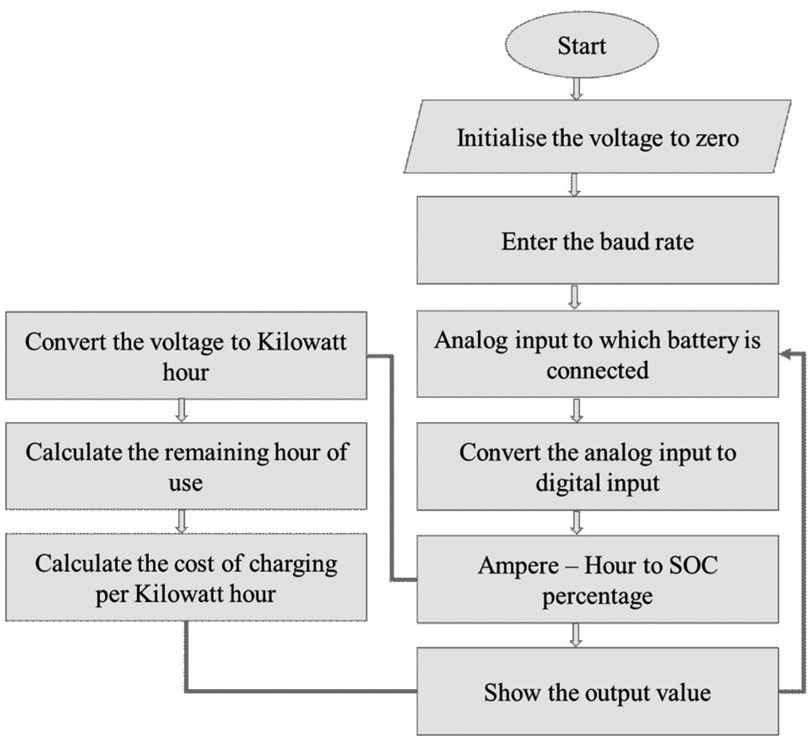

Figure 3: Flow chart for the determination of SOC

The SOC is measured using the following equations (3), (4), (5) and (6)

$$\text{Amps} = \frac{\text{Voltage}}{0.060} \tag{3}$$

$$\text{Watts} = \text{Amps} \times \text{Voltage} \tag{4}$$

$$\text{Amphours} = \frac{\text{Amps} \times \text{Time}}{3600} \quad (5)$$

$$\text{SOC} = \frac{400 - \text{Amphours}}{400} \times 100 \quad (6)$$

A. Monitoring the battery SOC

Hardware implementation includes the connection of battery with the Arduino UNO board and then monitoring the voltage of the battery. In this the battery is connected to one end of the voltage divider and the other end of the voltage divider is connected to the pin A_0 of the Arduino UNO board.

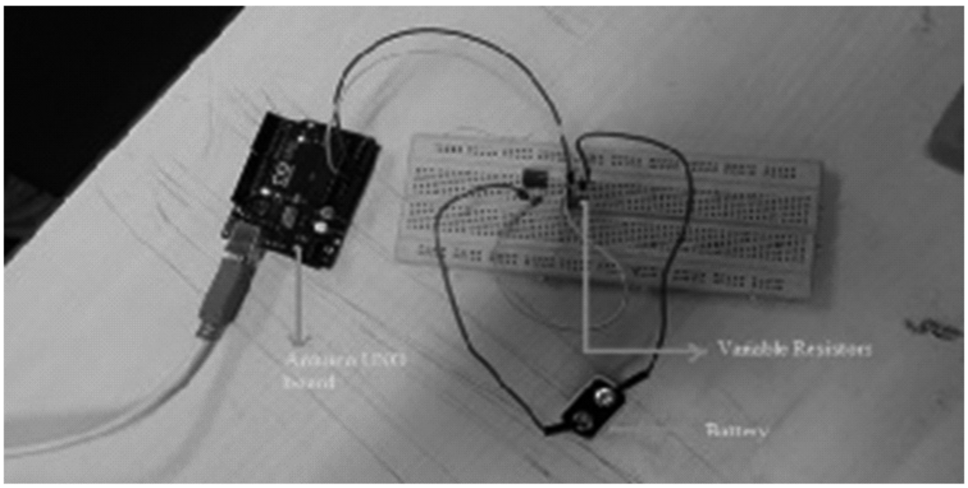

Figure 4: Monitoring the battery voltage

The ground pin is connected to the negative terminal of the battery. In this the voltage of 9V battery is measured and it is displayed in the PC using the serial port which has the baud rate of 9600. The voltage measured is 8.54 V for a 9 V battery. The battery voltage is measured using the voltage divider rule. The connection of 9 V Battery to the Arduino UNO is shown in the above Figure 4.

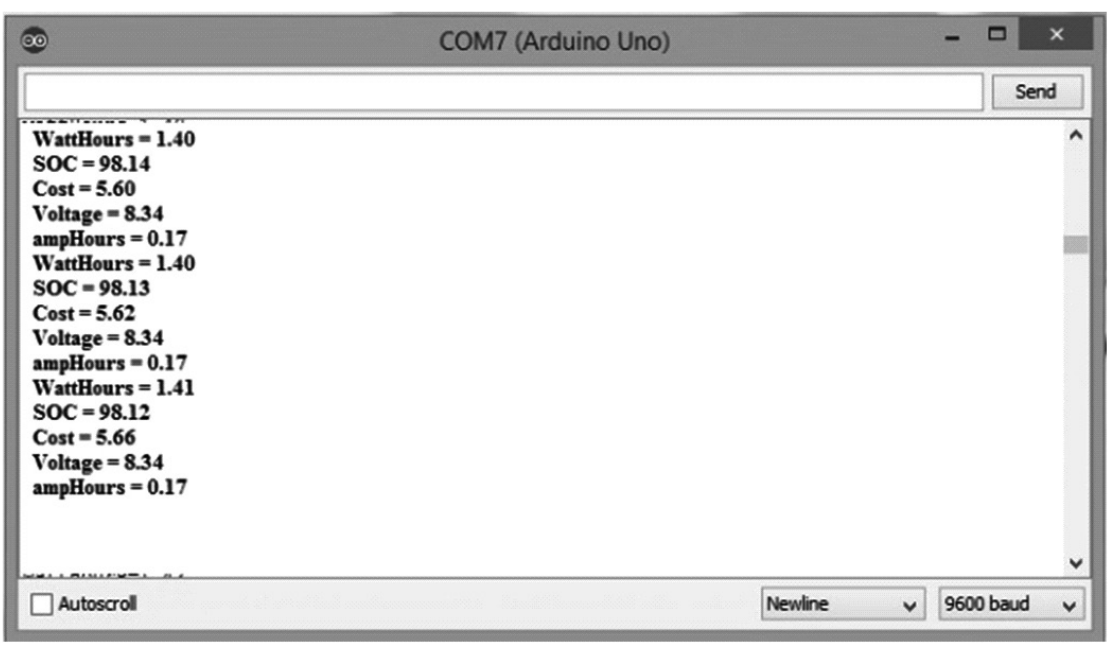

Figure 5: Battery Voltage - Display

B. Arduino – Bluetooth Interface

The Figure 6 shows the interfacing of the Bluetooth Module to arduino for receiving the battery voltage and SOC from the arduino to android mobile. The key pin of the Bluetooth module is connected to the 3.3V of the arduino board, the VCC pin is connected to the 5V pin of the arduino. The TX pin of the Bluetooth module is connected with the RX pin of the arduino board. The RX pin of the Bluetooth module is connected with the TX pin of the arduino board. The battery voltage is communicated to the android via the Bluetooth module. The Bluetooth module used here is HC – 05. It supports the baud rate 9600. The Voltage is then displayed in the android is shown in Figure 6.

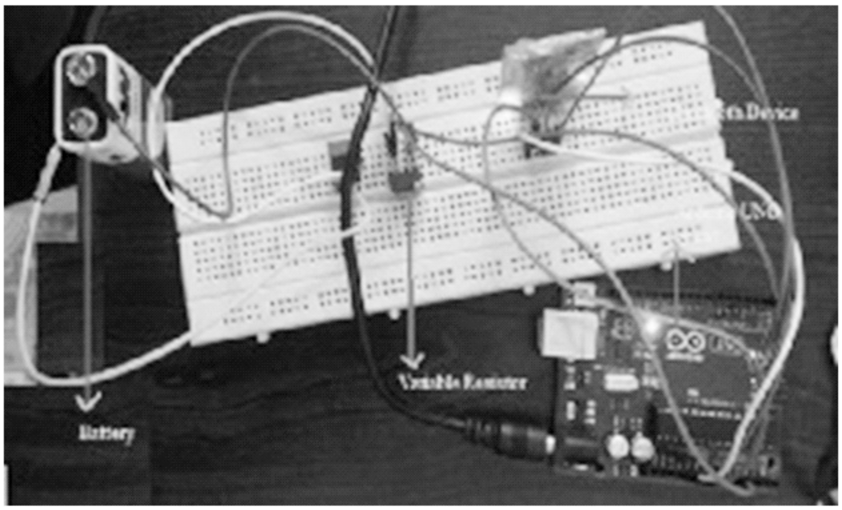

Figure 6: Arduino – Bluetooth Interface

C. Algorithm for Route Prediction

Charging Station Selection server (CSS) traces the instantaneous location of a vehicle and taps the range available with it. It proposes all the charging stations covering the limit.CSS communicates with other vehicles to determine the road traffic and gives an approximate time and charge remaining, until a specific charging station is reached. It also suggests an alternate route to the nearest charging station in case of heavy traffic. The driver chooses the charging type and blocks a slot considering least waiting time. The CSS uses mobile network to communicate with the vehicle and CSs. It also proposes the current metering scheme at particular CS and compares with other CS price. It also can be done through a demand based metering system where EVs will be charged according to peak time and peak load.

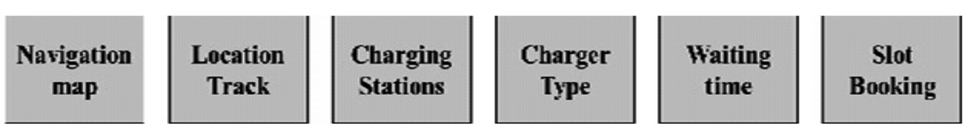

Figure 7: Route Prediction Algorithm

D. Distance Estimation

Speed, Battery pack KW rating, driving conditions, aerodynamics, vehicle weight, hills, temperature, driving styles and several others play a vital role in the distance prediction. Here the Battery pack KW rating and the speed is considered for the distance estimation. The equations (7), (8) and (9) are used for the distance estimation.

$$\text{Distance} = \frac{\text{Battery pack size(KW)}}{\text{Watt-hour/mile}} \tag{7}$$

$$\frac{\text{Watt-hour}}{\text{mile}} = \text{Volts} \times \left(\frac{\text{Ampere draw}}{\text{mile per hour}} \right) \tag{8}$$

$$\text{Battery pack size (KW)} = \text{pack voltage} \times \text{Amp-Hour rating} \tag{9}$$

4. CONCLUSION

The main aim is to develop an android application for the electric vehicle users. It mainly concentrates on measuring the battery state of charge. After measuring the SOC it must be communicated to the android application via the Bluetooth module (HC – 05). An algorithm must be developed in order to predict whether the destination can be reached with the current state of charge in the electric vehicles battery. And to evaluate this Google maps are integrated with the temperature according to that also the prediction of reaching the destination can be done. The charging station serves the electric vehicles based on the token system so requesting for the token in the charging station is also included in the android application. Mainly the android application was developed for the convenience of electrical users. For the future implementation the bidding process can be used in the allocation of parking lot to the electrical users.

References

1. M.A.Hannan, F.A.Azidin, A.Mohamed, "*Hybrid Electric vehicles and Their Challenges*", Renewable and Sustainable Energy Reviews 29(2014) 135–150
2. A. Y. Saber and G. K. Venayagamoorthy, "*Plug-in vehicles and renewable energy sources for cost and emission reductions*," IEEE Trans. Ind. Electron., Vol. 58, No. 4, pp. 1229–1238, Apr. 2011.
3. Yunyan Wang, Jingxin Li, Jiuchun Jiang, Liyong Niu, "*Management Information System of Charging Station for Electric Vehicle (EV)*," National High Technology Research and Development Program of China.
4. P. Simonik, A. Havel, M. Hromjak, and P. Chlebis, "*Active Charging Stations for Electric Vehicles Charging*", Electromagnetics Research Symposium Proceedings, KL, MALAYSIA, March 27, 2012
5. Charles Botsford, Adam Szczepanek, "*Fast Charging vs. Slow Charging: Pros and cons for the New Age of Electric Vehicles*," EVS24 Stavanger, Norway, May 13-16, 2009.
6. Praveen Kumar and Kalyan Dash, "*Potential Need for Electric Vehicles, Charging Station Infrastructure and its Challenges for the Indian Market*", Advance in Electronic and Electric Engineering. ISSN 2231-1297, Volume 3, Number 4 (2013), pp. 471-476
7. Wenbo Shi, Eun-Kyu Lee, Daoyuan Yao, Rui Huang, Chi- Cheng Chu, and RajitGadh, "*Evaluating Microgrid Management and Control with an Implementable Energy Management System*" Smart Grid Energy Research Center University of California, IEEE International Conference on Smart Grid Communication 3-6 November-2014..
8. M. Verbrugge, D. Frisch, and B. Koch, "*Adaptive Energy Management of Electric and Hybrid Electric Vehicles*," Journal of Power Sources, 2005.
9. Minghao AI, Linhai QI ,"*Orderly Charging Based Electric Vehicle Charging Stations' On-Line Monitoring System*", CIRED Workshop - Rome, 11-12 June 2014
10. Mukesh Singh, Praveen Kumar, and Indrani Kar, "*Implementation of Vehicle to Grid Infrastructure Using Fuzzy Logic Controller*," IEEE transactions on smart grid, Vol. 3, No. 1, march 2012.
11. Ricardo Faria, Pedro Moura, Joaquim Delgado, and Aníbal T. de Almeida, "*Managing the Charging of Electrical Vehicles: Impacts on the Electrical Grid and on the Environment*" , IEEE Intelligent transportation systems magazine.
12. Fabian Kennel, Daniel Görges, and Steven Liu, "*Energy Management for Smart Grids with Electric Vehicles Based on Hierarchical MPC*," IEEE transactions on industrial informatics, Vol. 9, No. 3, august 2013
13. A. Moreno-Muñoz, V. Pallarés-López, J. J. G. de la Rosa, R. Real-Calvo, M. González-Redondo, and I. M. Moreno-García, "*Embedding synchronized measurement technology for smart grid development*," IEEE Trans.Ind. In format., Vol. 9, No. 1, pp. 52–61, Feb. 2013.
14. V. Gungor, D. Sahin, T. Kocak, S. Ergut, C. Buccella, C. Cecati, and G. Hancke, "*Smart grid technologies: Communications technologies and standards*," IEEE Trans. Ind. Informat., Vol. 7, No. 4, pp. 529–539, Nov. 2011.

15. G. A. Shah, V. C. Gungor, and O. B. Akan, "*A cross-layer QoS-aware communication framework in cognitive radio sensor networks for smart grid applications*," IEEE Trans. Ind. Informat., Vol. 9, No. 3, pp. 1477–1485, Aug. 2013.

16. V. C. Gungor, B. Lu, and G. P. Hancke, "*Opportunities and challenges of wireless sensor networks in smart grid*," IEEE Trans. Ind. Informat., Vol. 57, No. 10, pp. 3557–3564, Oct. 2010.

17. P. P. Parikh, T. S. Sidhu, and A. Shami, "*A comprehensive investigation of wireless LAN for IEC 61850-based smart distribution substation applications*," IEEE Trans. Ind. Informat., Vol. 9, No. 3, pp. 1466–1476,Aug. 2013.

18. A. Sabbah, A. El-Mougy, and M. Ibnkahla, "*A survey of networking challenges and routing protocols in smart grids*," IEEE Trans. Ind. Informat., Vol. 9, No. 1, pp. 1551–3203, Feb. 2013.

19. J. C. Ferreira, V. Monteiro, J. L. Afonso, and A. Silva, "*Smart electric vehicle charging system*," in Proc. IEEE IVS Intell. Veh. Symp., Baden-Baden, Germany, Jun. 2011, pp. 758–763.

20. P. Simonik, A. Havel, M. Hromjak, and P. Chlebis, "*Active Charging Stations for Electric Vehicles Charging*," Progress In Electromagnetics Research Symposium Proceedings, KL, MALAYSIA, March 27-30, 2012, pp. 995-998

21. Haiying Wang, Yang Liu, Hang Fu and Gechen Li, "*Estimation of State of Charge of Batteries for Electric Vehicles*," International Journal of Control and Automation, Vol. 6, No. 2, April, 2013.

22. J. C. Ferreira, A. Silva, and J. L. Afonso, "*EV-cockpit—Mobile personal travel assistance for electric vehicles*," Microsystems for Automotive Applications. Smart Systems for Electric, Safe and Networked Mobility, Berlin, Germany: Springer, 2011, pp. 247–257.

23. Ganta Naveen, Tony Ho-Tung Yip, Yuyu Xie, "*Modeling and Protection of Electric Vehicle Charging Station*".

24. Fabian Kennel, Daniel Görges, and Steven Liu, "*Energy Management for Smart Grids with Electric Vehicles Based on Hierarchical MPC*," IEEE transactions on industrial informatics, Vol. 9, No. 3, august 2013.

25. Madhuri Unde, Bharat Borkar, "*Remote Vehicle Tracking & Driver Health Monitoring System Using GSM Modem & Google Maps*", International Journal of Computer Science and Information Technologies, Vol. 5 (3), 2014, 2828-2832

26. Melike Erol-Kantarci, Hussein T. Mouftah, "*Wireless Sensor Networks for Cost-Efficient Residential Energy Management in the Smart Grid*", IEEE Transactions on Smart Grid, Vol. 2, No. 2, June 2011

27. SeokJu Lee, Girma Tewolde, Jaerock Kwon, "*Design and Implementation of Vehicle Tracking System Using GPS/GSM/GPRS Technology and Smartphone Application*", IEEE World Forum on Internet of Things (WF-IoT) 2014

28. Pankaj Verma, J.S Bhatia, "*Design And Development Of GPS-GSM Based Tracking System With Google map Based Monitoring*", International Journal of Computer Science, Engineering and Applications (IJCSEA) Vol. 3, No. 3, June 2013

29. Lin Ch T, Wang J P and Chen Q S, Methods for state of charge estimation of EV batteries and their application, Battery Bimonthly, 2004, Vol. 34, No. 5, pp. 376-378.

30. Pooja Sathe, "*GPRS Based Routing & Tracking of Mobile Vehicles Using Arm*", International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 4, July-August 2012, pp.1088-1090.

31. Daniel Chang, Daniel Erstad, Ellen Lin, Alicia Falken Rice, Chia Tzun Goh, An-An (Angel), Tsao, "*Financial Viability Of Non-Residential Electric Vehicle Charging Stations*", August 2012.

32. Strnad , D. Skrlee, and T. Tomisa, "*A Model for the Efficient Use of Electricity Produced From Renewable Energy Sources for Electric Vehicle Charging*", 978-1-4673-5556-8/13/$31.00 ©2013 IEEE.

33. P. Goli, W. Shireen, "*PV powered smart charging station for PHEVs*", Renewable Energy 66 (2014) 280e287.

34. Shamna P V, Beena M Varghese, "*State-of-Charge Estimation of Lithium-Ion Batteries Combining Current and Voltage Based Estimation*", International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 12, June 2013 ISSN: 2277-3754 pp. 128 – 137.